

Radioactive Waste Management in A Hospital

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Abstract: Most of the tertiary care hospitals use radioisotopes for diagnostic and therapeutic applications. Safe disposal of the radioactive waste is a vital component of the overall management of the hospital waste. An important objective in radioactive waste management is to ensure that the radiation exposure to an individual (Public, Radiation worker, Patient) and the environment does not exceed the prescribed safe limits. Disposal of Radioactive waste in public domain is undertaken in accordance with the Atomic Energy (Safe disposal of radioactive waste) rules of 1987 promulgated by the Indian Central Government Atomic Energy Act 1962. Any prospective plan of a hospital that intends using radioisotopes for diagnostic and therapeutic procedures needs to have sufficient infrastructural and manpower resources to keep its ambient radiation levels within specified safe limits. Regular monitoring of hospital area and radiation workers is mandatory to assess the quality of radiation safety. Records should be maintained to identify the quality and quantity of radioactive waste generated and the mode of its disposal. Radiation Safety officer plays a key role in the waste disposal operations.

Key Words: Radioactive, Waste, Disposal, Safe, Radiation, Regulation.

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Introduction

Healthcare institutions generate enormous amount of waste which is considered as potentially hazardous in view of the inherent potential for dissemination of infection. Hospitals generate on an average, between 0.5 and two kilograms of waste per bed per day ⁽¹⁾. It is estimated that about 85% of the waste generated is non-hazardous, about ten percent is infectious and 5% non-infectious but hazardous. The rising trends of HBV and HIV infection has led to an increasing awareness about the risk associated with improper management of biomedical waste and the need to evolve and implement strategies for safe and sustainable methods of disposal of waste ⁽¹⁾.

Hospitals are increasingly using radioactive isotopes for diagnostic and therapeutic applications. The main radioisotopes used in hospitals are technetium-99m (Tc-99m), Iodine-131(I-131), Iodine-125 (I-125), Iodine-123(I-123), Fluorine-18(F-18), Tritium (H-3) and Carbon-14(C-14). The bulk of the hospital radioactive waste gets generated in the department of Nuclear Medicine. More than 200 Nuclear Medicine centers in India, that include five independent Positron Emission Tomography (PET) centers, are currently performing approximately 1.25 million studies annually. Most of the radioactive waste is liquid, with lesser amount of solid and minimal gaseous. The solid waste containing traces of radioactivity is in the form of syringes, needles, cotton swabs, vials, contaminated gloves and absorbent materials. Clothing and utensils of patients administered high doses of radioisotopes like I-131 constitute the solid radioactive waste material. Safe disposal of unused radioactive material and objects contaminated with it is a vital component of the overall strategy of hospital waste management. The fundamental objective of safe

disposal of radioactive waste is to ensure that the radiation exposure to public, radiation workers and environment does not exceed the prescribed safe limits^(2,3). Keeping the exposure levels within the prescribed limits reduces the short term and long-term effects of ionizing radiations on humans, besides reducing its negative impact on environment. Any prospective plan for a hospital or clinical facility that envisages the use of radioactive isotopes needs to ensure structural and functional parameters to keep the environmental radiation levels and personal radiation exposure of workers and public within the permissible limits Table (1). In addition to the management of radioactive hospital waste on scientific lines, the basic principals for radiation protection to be adopted are, justification of practice (use radiation only if benefits outweigh the risks), optimization of practice (keep magnitude of individual dose and number of people exposed to as low as reasonably achievable, ALARA) and dose limitation⁽⁴⁾. Regular personal monitoring of hospital radiation workers, area monitoring of hospital environment and quality control of the radiation instruments is mandatory to assess the quality of existing radiation safety standards.⁽⁵⁾ Every hospital should have a designated Radiation Safety Officer (RSO) who oversees all aspects of radiation safety including radioactive waste management. The RSO co-ordinates such measures in accordance with guidelines prescribed by the International Commission on Radiation Protection and the national regulatory body^(6,7).

There are strong economic and social reasons for aggressively protecting the environment by managing the biomedical waste scientifically, so essential for sustainable development⁽¹⁾.

Table (1). Dose Limits.

Application	Annual Dose Limit	
	Occupational	Public
Effective Dose*	20 mSv	1 mSv
Equivalent Dose to Organs		
Eye Lens	150 mSv	150 mSv
Skin**	500 mSv	50 mSv
Hands and Feet.	500 mSv	-
Equivalent Dose		
Pregnant Women	2 mSv to abdomen, from declaration to termination of pregnancy	-

* The dose is averaged over 5 years. In no case more than 30 mSv/year (AERB)

** Averaged over area no more than 1 cm sq, regardless of area exposed.

Basic Concepts in Radioactive Waste Management

A unit is necessary for measurement of any physical quantity. The International Commission on Radiation Units and Measurement (ICRU) reviews and updates, from time to time, the concepts related to quantities and their units in radiation physics that are important for radioactive waste management.^(8,9)

Activity (Quantity) of radioactive material

Old unit

Curie (Ci), millicuries (mCi) etc.

Standard international unit (SI)

Becquerel (Bq).

Relative biological effectiveness (Equivalent dose/ Effective dose)

Exposure to different types of radiations (Gamma rays, X-rays, Alpha rays, Beta rays, Neutrons etc) differ in the extent of causing biological damage due to differences in their tissue damaging (ionization) properties. A unit exposure of gamma rays or X-rays will be less biologically damaging than unit exposure of alpha rays. Based on the biological damage caused, the following units are used.

Old unit REM

SI unit Sievert (Sv), milliSievert (mSv) etc.

Half-life of a Radioisotope

This is defined as the time interval for a particular radioactive material to reduce (decay) its radioactivity by half. For example, if there are 10 millicuries (mCi) of a commonly used diagnostic radioisotope Tc-99m at 2 pm, since its half life is 6 hours, the remaining activity at 8 pm will be 5 mCi. Different isotopes have different half-lives. For practical considerations, a simple fact to remember is that the radioactivity remaining after 10 half-lives of a radioisotope is about one-thousand of the original radioactivity (i.e., millicurie amounts are reduced to microcurie amounts). Half lives of some commonly used radioisotopes are,

Technetium-99m (Tc-99m)	6 hours.
Iodine-131 (I-131)	8 days.
Flourine-18 (F-18)	110 minutes.
Cobalt-60 (Co-60)	5.271 years.

Tenth -value thickness (TVT)

This is defined as the thickness of an absorber or shielding material that decreases

the transmitted beam intensity by a factor of 10 or 0.1% of its original intensity.

TVT of lead, the commonly used shielding material for some of the isotopes:

Radioisotope	Photon Energy (keV)	TVT in Lead (mm)
Technetium-99m.	140	0.9
Iodine-131	364	7.7
Iodine-125	27.5	0.06
Xenon-133	81	1.0
Cobalt-60	1330	36.2
Flourine-18	511	13.5

Commonly used Radioactivity / Radiation measuring and monitoring devices

Well counter:

Scintillation based sensitive system for measuring radioactivity, mostly gamma rays.

Dose calibrator:

Ionization based chamber used for measuring radioactivity.

Gun monitor:

Ionization based portable survey meter used mostly for radiation monitoring.

Geiger Muller (GM) Counter:

Ionization based sensitive system for detecting minutest levels of radiation contamination

Film badge:

Photographic film based personnel dose monitoring.

TLD badge:

Thermoluminescent dosimeter for personnel dose monitoring.

Pocket Dosimeter:

Ionization based personnel dose monitor that provides instant readout.

Classification of Radioactive Waste

Radioactive waste can be classified in following ways.

According to level of activity:

High level waste

Medium level waste

Low level waste

According to the form:

Solid waste

Liquid waste

Gaseous Waste

According to half- life:

Long half-life waste (Half-life more than a month)

Short half-life waste (Half-life less than a month)

The hospital radioactive waste is mostly composed of low level waste and occasional medium level waste with short half-lives. The high level waste is usually associated with nuclear industry and nuclear reactors.

Radioactive Waste Management in a Hospital

The management of radioactive waste involves two stages: collection and disposal.

The radioactive waste should be identified and segregated within the area of work. Foot operated waste collection bins with disposable polythene lining should be used for collecting solid radioactive waste and polythene carboys for liquid waste. Collecting radioactive waste in glassware should be avoided. Each package is monitored and labeled for the activity level before deciding upon the mode of disposal. Some hospitals that have incinerators and permission to dispose of combustible radioactive waste through incineration may also segregate combustible radioactive waste from non-combustible waste. When two different isotopes of different half-lives like Tc-99m and I-131 are used, separate waste collection bags and bins should be used for each. Each bag or bin must bear a

label with name of the isotope, level of activity and date of monitoring.

Radioactive waste disposal

The collected radioactive waste is disposed as per the following:

Dilute and Disperse

Delay and Decay

Concentrate & Contain (Rarely used)

Incineration (Rarely used)

Dilute and Disperse:

Low activity solid article may be disposed off as ordinary hospital waste provided the activity of the article does not exceed 1.35 microcuries (50 KBq) or the overall package concentration does not exceed 135 microcuries / m³ (5MBq / m³). Such articles include vials, syringes, cotton swabs, tissue papers etc. Similarly, liquid radioactive waste with activity less than microcurie level can be disposed off into the sanitary sewerage system with adequate flushing with water following the disposal. However, the maximum limit of total discharge of liquid radioactive material into sanitary sewerage system should not exceed the prescribed limits Table (2).

Table (2). Disposal limits for Sanitary Sewerage System.

Radioisotope	Maximum Limit on total discharge per day (MBq)	Average monthly activity in discharge MBq/m ³
Hydrogen-3 (Tritium)	92.5	3700
Carbon-14	18.5	740
Sodium-24	3.7	222
Phosphorus-32	3.7	18.5
Sulphur-35	18.5	74
Calcium-45	3.7	10.1
Moly99m+Technetium99m.	3.7	185
Iodine-125	3.7	22.2
Iodine-131	3.7	22.2

The gross quantity of radioactive material released into the sewerage system by any hospital should not exceed 37 GBq (1 Curie) in one year.

Delay and Decay:

Medium activity radioactive waste and those with half-lives of less than a month may be stored. The storage room should be properly ventilated with an exhaust system conducted through a duct line to a roof top exit. The storage space should have lead shielding of appropriate thickness (10 HVL) to prevent radiation leakage. The radioactive waste should be stored for a minimum period of about 10 half lives when after decay only 0.1% of the initial activity remains. The waste is then monitored for the residual activity and if the dose limit is low it is disposed off as low activity solid or liquid waste. Most of the low and medium level radioactive hospital waste is of short half-life permitting this type of waste disposal.

Concentrate and Contain

This technique of radioactive waste disposal is sometimes used for radioactive materials with very high activity levels and for those with long half-lives (longer than a month). Their disposal by delay and decay method is impractical because of longer storage period, particularly if space availability is limited. Radioactive waste is collected in suitably designed and labeled containers and then buried in exclusive burial sites approved by the competent authority. In day-to-day work of a hospital, we do not come across radioactive waste of this nature and as such, this method of radioactive waste disposal is rarely used.

Incineration

Insoluble liquid waste such as that from the liquid scintillation systems may be disposed off by incineration. Incineration reduces the bulk of waste and the activity is concentrated in a smaller volume of ash for further disposal. Since incinerators used for radioactive waste disposal release part of the radioactivity into the atmosphere they should operate under controlled conditions and in segregated places. Ashes collected have to be disposed off as solid radioactive waste separately.

Environmental concerns and public pressure severely restrict the methods of ground burial and incineration as regular options of radioactive waste disposal. For these reasons, incineration and burial are rarely recommended.

Special situations of Radioactive Waste Management in a Hospital***Disposal of sealed sources***

Hospitals use sealed sources for a variety of applications, including teletherapy, brachytherapy, blood irradiation, calibration etc. Most of these sources are relatively small with activities ranging from a few up to a few hundred MBq, except the teletherapy and blood irradiation source, which may have high activities. Once the source becomes weak for further applications it has to be removed and replaced. Hospitals ordering and using such equipments must enter into a contract for safe removal and replacement of the sealed radioactive source with the suppliers. While ordering such equipment and the source, the Radiation Safety Officer of the hospital should be taken into confidence.

Disposal of gaseous waste

Volatile radioactive sources like Iodine-131 and Iodine-125 release radioactive vapors, generating airborne radioactive waste. The containers of such radioactive substances should be opened under fume hoods connected through duct lines to highest roof top exit. Before the vapors are diluted and dispersed into the atmosphere, they should pass through charcoal and particulate air filters. Hospitals using radioactive gases should have efficient laminar airflow system. Other gaseous radioactive waste generating isotopes used are Xenon-133, Carbon-14, Hydrogen-3, Nitrogen-13, Technetium-99m aerosols.

Disposal of excreta and urine of patients administered high doses of radioisotopes:

Patients administered high therapeutic doses of radioisotopes (e.g., Iodine-131 in thyroid cancer) are admitted in isolation wards until their radiation emission levels are within the minimum safe limits (3 mRoentgens per / Hour at 1meter distance). The excreta and urine of patients admitted in a high dose isolation ward (e.g. Iodine -131) after getting flushed passes the PVC pipes through the shortest route possible into customized storage tanks, called delay tanks for storage before dispersal into the sewerage system (Fig:1). The delay tank should be located in an area where there is minimal movement of public.⁽¹⁰⁾ The tank should be leak proof, corrosion free

and should have smooth surface from inside. The capacity of the tank depends on the number of patients admitted each day. A facility admitting two patients would require two delay tanks of 6000 liters each. This capacity is based on the presumption that on an average each patient uses about 100 liters of water per day. At that rate, each patient will use 3000 liters per month and two patients will use 6000 liters. At the end of one month as the tank will be full, it is closed and the gate valve of the second tank is opened. The full tank is kept

closed for the period of one month that the second tank takes to fill. As such, each tank holds the radioactive waste for 2 months that is sufficient for the decay of Iodine-131 to low levels (Delay & Decay). However before releasing the effluent of the tank into the public sewerage system a sample is collected to check the activity, this should not be more than 1.2 microcuries per liter. No hospital is permitted to release into public sewerage system an aggregate 37 G Bq (1 Curie) of liquid radioactive waste in one year.⁽¹¹⁾

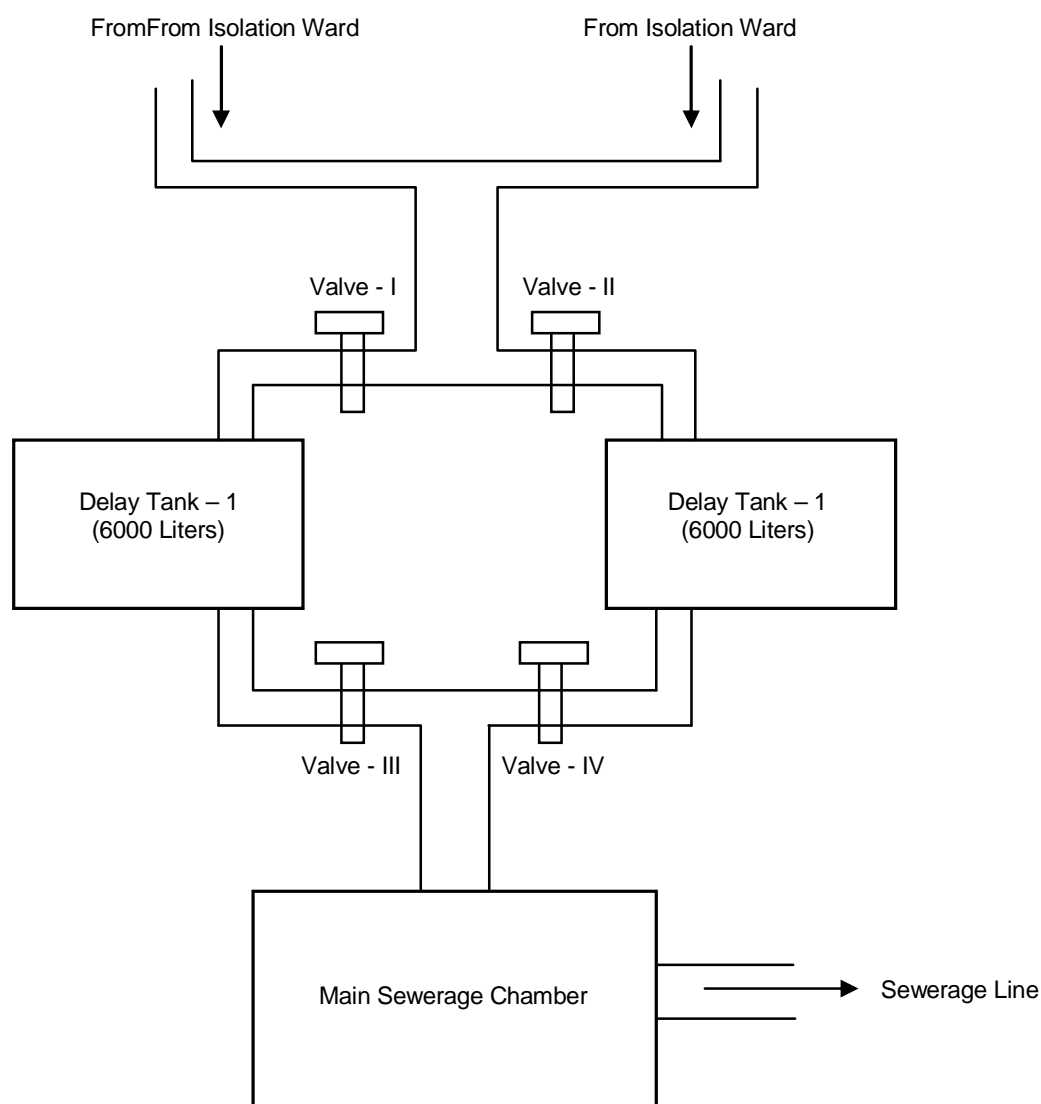


Fig. (1). Typical dual delay tank system for two patients.

Management of cadavers containing radioactive material:

Sometimes a situation may arise when a patient suffering from a disease such as thyroid cancer is administered a high dose of iodine-131 and the patient dies while she or he is in the hospital and still has very high levels of radioactivity in her or his body. In such a situation, one has to inform the Radiation Safety Officers who in collaboration with the Nuclear Physician supervise the future course of action. If high activity is concentrated in an organ like residual thyroid, then the same may need to be removed (Autopsy). If the activity is in a metastatic site, an effort to remove that site may also be undertaken. Once it is established that the cadaver has radioactivity less than the safe limit recommended by the competent authority Table (3), the dead body may be handed over for disposal through burial or cremation without any special precautions.⁽¹¹⁾ In case, the levels of radioactivity are high than the corpse is retained in the hospital mortuary until the activity decays to safe limits.

Advisory / Regulatory bodies and Record keeping

The usage of radioisotopes and disposal of radioactive waste is done in accordance to recommendations and guidelines issued by various international and national bodies. Institutional Head, Departmental Head, and Radiation Safety Officer of the institution have to co-ordinate their activities with the national regulatory body. Authorisation for procurement, usage and disposal of radioactive waste from the regulatory body is mandatory. The following bodies play key roles in ensuring safe use of radioisotopes and safe disposal of the radioactive waste.

International Commission on Radiological Protection (ICRP):

This body was founded in 1928, under the then name of "International X-ray and Radium Protection Committee." ICRP is an international advisory body providing recommendations and guidance on radiation protection.⁽¹²⁾ The secretariat of this body is located in Sweden (www.icrp.org).

Atomic Energy Regulatory Board (AERB) of India:

This national apex regulatory body was constituted in 1983 to perform certain regulatory and safety functions. The main mission of AERB is to ensure that the use of ionizing radiations and nuclear energy in India does not cause undue risk to health and environment.⁽¹³⁾ The Atomic Energy Act of 1962 governs the use of radioactive materials and radiation generating equipment. Under section 30 of this Act; the Central Government has issued The Atomic Energy (Safe disposal of radioactive waste) Rules, GSR-125, 1987. The AERB safety code includes salient recommendations on disposal of radioactive waste (SC/Med/4). The Chairman of the AERB is designated as the Competent Authority to enforce these rules. The employer, which may be the Head of the institution, shall obtain an authorization from the Competent Authority for disposal of radioactive waste either locally or through authorized waste disposal agency. The Chairman, AERB may issue Surveillance procedures, codes, standards, and guides which elaborate the provisions of Rules for implementation. The office of AERB is located in Mumbai (www.aerb.gov.in).

Table (3). Maximum radioactivity for disposal of a corpse without special precautions (MBq).

Radioisotope	Post-mortem / Embalming	Burial	Cremation
Iodine-131	10 (1)	400 (3)	400 (3)
Yttrium-90 Colloid	200 (1)	2000 (4)	70 (5)
Gold- 198	400 (1)	400 (3)	100 (5)
Phosphorus-32	100 (1)	2000 (4)	30 (5)
Strontium-89	50 (1)	2000 (4)	20 (5)

(1) Based on contamination hazard.

(2) Based on extremity dose limit.

(3) Based on dose rate external to the body.

(4) Based on brehmsstrahlung dose at 0.5m.

(5) Based on contamination hazard that these radioisotopes remain in ash.

Radiation Safety Officer (RSO):

The employer shall employ a RSO with the requisite minimum qualification approved by the competent authority (AERB). The RSO shall advise and assist the employer in safe disposal of radioactive waste in accordance to the guidelines issued from time to time by the competent authority. The RSO has the key role to ensure all aspects of radiation safety, including safe disposal of radioactive waste in the institution. However, the ultimate responsibility for the same rests with the employer.

Record Keeping:

Proper records in the form of logbook must be maintained. Details of diagnostic and therapeutic radioisotopes procured and administered should be recorded. The records must also include the details of radioactive waste generated with the activity levels and the levels at the time of their disposal. The activity levels in the effluent of delay tank must be recorded prior to disposal into public sewerage system. The total activity disposed off annually in the sewerage system should be recorded. The names of persons authorized for administration and disposal of radioisotopes must be recorded. In the event of death of a patient containing high levels of radioactivity, Chairman of AERB has to be informed. Annual records have to be furnished to AERB.

Conclusion

Modern day hospitals are increasingly using radioisotopes for diagnostic and therapeutic applications. PET scanning using a variety of radioactive positron emitters is emerging as a vital diagnostic tool in cardiology and oncology. All of this will lead to an increase in the amount of radioactive hospital waste. This waste will have to be disposed off in accordance to the guidelines provided by the International Atomic Energy Agency (IAEA) and regulated by national agencies like Atomic Energy Regulatory Board (AERB) of India. An institutional coordinated effort within the National legal framework will ensure that the radiation exposure to humans and environment remains within the permissible limits. Safe disposal of the radioactive waste is a vital component of this effort.

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